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BIOLOGICAL STUDIES OF THE GREEN CLOVER WORM

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INTRODUCTION [1]

The green clover worm, *Plathypena scabra* Fabr., has long been recognized as a pest of wide distribution and injurious to various crops. In 1914 and 1915 it occurred in abundance in alfalfa fields in the vicinity of Nashville, Tenn., and studies on its life history were commenced by the writer at that time. During the summer of 1919 a general outbreak of this pest on different crops occurred of sufficient severity to attract the attention of agriculturists throughout a large portion of the East. A popular account with recommendations for control as an alfalfa pest, based on studies conducted by the writer in Tennessee, was published (*5*) [2] in 1918. The present bulletin embodies technical details regarding the biology of this insect which necessarily were omitted in the popular account.

SYSTEMATIC HISTORY

Owing to sexual dimorphism in this species, the sexes were originally considered as distinct species, a mistake which was not discovered until 1873, when Lintner (*7*), through study of his own collection and those of others, found that the species, then known as *Hypena scabra* Fabr. and *Hypena erectalis* Guen., were each represented in collections by a single sex. He communicated this observation to Grote, who substantiated it by further examinations; and later in the year both men published the fact that *erectalis* Guenée was merely the female form of *scabra* Fabricius, of which heretofore only the male form had been known. Grote (*3*), in his paper, erected for the species the genus Plathypena.

[1] The author expresses his appreciation of helpful suggestions, received from Geo. G. Ainslie, under whose direction work on this insect was first started at Nashville, Tenn., and to Carl Heinrich for guidance in the construction of pupal and setal charts.

[2] Reference is made by number (italics) to "Literature cited," p. 19.

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SYNONYMY

The following synonymy is given in Barnes and McDunnough's list (*1*):

Plathypena Grt.
scabra Fabr.
erectalis Gn.
palpalis Hav.
obesalis Steph.
ab. *subrufalis* Grt.

GEOGRAPHICAL DISTRIBUTION

A study of all the available definite locality records shows that the species occurs throughout the United States and southern Canada east of the ninety-eighth meridian, except possibly along a portion of the Gulf coast and southern Florida, from which sections no data have been secured by the writer. The infested territory is represented by the shaded area in the map (fig. 1).

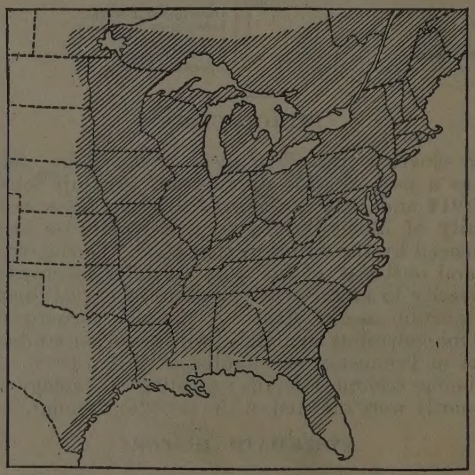

FIG. 1.—Map showing distribution of the green clover worm in the United States

FOOD PLANTS

The larvæ ordinarily feed on leguminous crops, and among forage crops are most frequently found on alfalfa, red clover, soybean, and cowpea. In Tennessee alfalfa seemed to be preferred above all other food plants. This was further demonstrated by caged material. Larvæ left in a cage containing red clover, cowpeas, blackberry, strawberry, and alfalfa attacked and stripped first the alfalfa plants.

In addition to these crops, Chittenden (*2*) recorded the larvæ from vetch and Lima bean, also at different times from both strawberry and blackberry, and in great numbers on tickweed, all in the vicinity of Washington, D. C.; E. H. Gibson found one feeding on sweet-clover and swept two more from the same plant; P. Luginbill reported

it injuring velvetbean, and Riley (*9*) stated that it fed on Robinia. In food-plant experiments conducted in Tennessee, larvæ were reared from egg to adult on common vetch, willow, strawberry, blackberry, and wild carrot, and they were found to feed greedily on dwarf Lima bean, white clover, alsike clover, tickweed, and common cinquefoil, and would undoubtedly mature on these plants under favorable conditions. Smartweed (*Persicaria pennsylvanica*) and morning-glory (*Ipomoea purpurea*) were eaten to some extent, and G. G. Ainslie found a partly grown larva on *Lespedeza procumbens*, upon which he succeeded in rearing it to adult.

In several instances larvæ have been found on grasses. P. Luginbill found a specimen on millet, and others on the leaves of *Paspalum dilatatum*. E. S. Cogan swept larvæ from grasses at the edge of a clover field, and E. H. Gibson swept them from grass and weeds growing in wheat stubble and along roadsides. None were seen in the act of feeding, and in each case it was likely that the larvæ had wandered from near-by leguminous plants. In Tennessee the writer did not succeed in rearing a single individual from egg to adult from any member of the grass family. Vigorous, newly hatched larvæ were offered barley, rye, Johnson grass (*Sorghum halepense*), and orchard grass (*Dactylis glomerata*) and refused them entirely. Corn and crabgrass (*Syntherisma sanguinale*) were eaten to some extent, but no larvæ matured on them. The negative results thus obtained from experiments with larvæ on cereals and grasses scarcely warrant including them as food plants.

The full list of known host plants includes the following:

Daucus carota	Wild carrot.
Fragaria virginiana	Virginia strawberry.
Lespedeza procumbens.	
Medicago sativa	Alfalfa.
Meibomia sp	Tickweed.
Melilotus alba	White sweetclover.
Phaseolus lunatus macrocarpus	Lima bean.
Pisum sativum	Common pea.
Potentilla canadensis	Common cinquefoil.
Rubus sp	Blackberry.
Salix sp	Willow.
Soja max	Soybean.
Stizolobium sp	Velvetbean.
Trifolium hybridum	Alsike clover.
Trifolium incarnatum	Crimson clover.
Trifolium pratense	Red clover.
Trifolium repens	White clover.
Vigna sinensis	Cowpea.
Vicia faba	Broadbean.
Vicia sativa	Common vetch.

DECRIPTION OF STAGES

THE ADULT

The moth (fig. 2) is dark brown and of moderate size, with wing expanse of about 1¼ inches. When at rest it resembles in outline an isosceles triangle with base slightly shorter than height. The sexes are easily distinguished by salient characters. The male is somewhat larger than the female, and more uniformly dark in color; the eyes and palpi are conspicuously larger; the antennæ are fringed their entire length with setæ much more numerous and longer than those found on

the female antennæ; and the frenulum on the male wings consists of one long, strong spine, as compared with two small, diverging spines on the female. (See fig. 3.)

The technical description of the adult by Smith (*11*) follows:

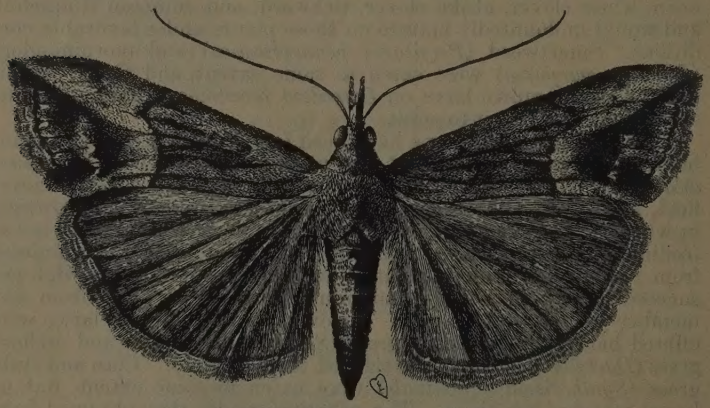

FIG. 2.—Adult of the green clover worm. Enlarged

Ground color a dark purplish or smoky brown. Head and thorax concolorous. Abdomen more smoky, like the secondaries. Primaries dusky to the transverse posterior line, then with bluish powderings, which scarcely relieve the somber tint in the male, but are quite contrasting in the female. In the latter sex the inferior half of the median space often becomes shaded with yellowish red-brown, sometimes quite contrastingly. Transverse anterior line red-brown, preceded by pale in the best marked specimens, outwardly bent, with three long outward angulations, rarely complete, and in the male quite frequently entirely obsolete. Transverse posterior line black or brown, outwardly bent over the cell and almost rigid beneath. The line is marked through the lower part of its course by elevated scales, which are most prominent on the inner margin. Subterminal line interrupted, pale, preceded by black spots, rather evenly bisinuate, often quite contrasting in the female, and as inconspicuous in the male. A brown terminal line, which is rarely interrupted, preceded by undefined bluish lunules in the interspaces. In the male the apex is blue powdered, the terminal space else quite even. In the female the apical patch is more contrasting, inferiorly limited by a blackish streak, the terminal space being irregularly and variably mottled with bluish brown and black. Opposite the hind angle is a longitudinal black mark, which crosses the subterminal line. Usually a narrow black line connects the median lines in the submedian interspace, and another connects the ordinary spots, which are much reduced and marked by black elevated scales. The basal space is also sometimes blue powdered or inferiorly brown. In the male the ordinary spots are sometimes hardly evident. Secondaries deep smoky-brown, varying a little in tinge toward brown or black. Beneath, uniformly brown or blackish; the secondaries with a more or less evident discal spot.

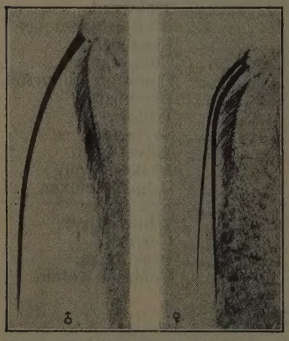

FIG. 3.—Frenulum of moth of green clover worm: Left, male; right, female. Much enlarged

Expanse of wings, 27 to 34 mm.=1.10 to 1.35 inches.

THE EGG (FIG. 4)

Width 0.510 millimeter, height 0.346 millimeter. Subglobose, flattened, circular at the equator, with polar axis about two-thirds length of diameter; 14 to 16 prominent, acute, longitudinal ridges running from base to apex, each alternate one slightly longer; interspaces concave and crossed by fine, transverse, regularly placed ridges; polar area sculptured by a few fine ridges; base flattened and taking impression of surface to which attached. Color when laid shiny pale green, sometimes distinctly bluish-green; partly developed eggs with pale orange spots and streaks scattered over upper surface, and in eggs still further advanced with orange spots turned to distinct, sparsely distributed, reddish brown spots. Shortly before hatching the egg turns a dark metallic purplish-gray color. The empty shell is colorless, transparent, and iridescent.

FIG. 4.—Egg of green clover worm. Enlarged

THE LARVA (FIG. 5)

First instar.—Length 1.5 to 4 millimeters, head width 0.265 to 0.285 millimeter. The newly hatched larva is slender and much constricted between segments. Head considerably wider than body; shiny, transparent, with faint yellow tinge. Body translucent grayish-white, with alimentary canal slightly darker. As the larva develops the body becomes faintly yellowish, usually tinged with green from chlorophyll in the alimentary canal. Throughout this instar the first three abdominal segments are considerably larger than the others; the next four are about equal in size; the eighth, of the same width, is considerably longer; the ninth is shorter and narrower than any except the tenth and last, which is still shorter. The constrictions are deepest between the first four abdominal segments. Prolegs on the third and fourth segments rudimentary, those on fifth, sixth, and last functional. Head oblique, somewhat flattened, pale, shiny, transparent, yellowish, tinged with green, caudal edge dark. Numerous short setæ are scattered over the face, with one long one on either side of frons. Setæ for the most part dark and moderately long, borne on small chitinizations slightly darker than surrounding tissues.

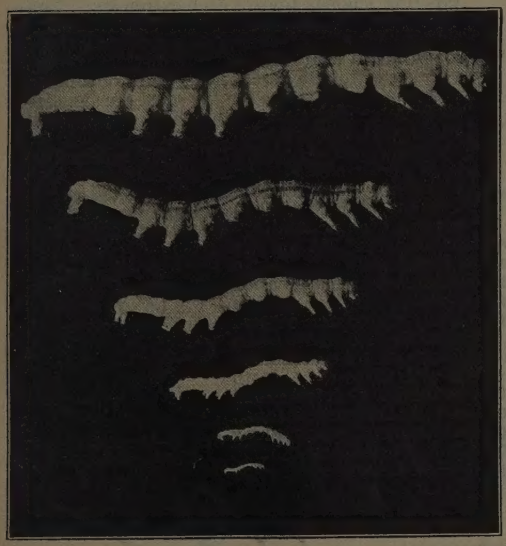

FIG. 5.—Photograph showing a comparison of the six larval instars of the green clover worm. Enlarged

Second instar.—Length 3.5 to 7.5 millimeters, head width 0.353 to 0.459 millimeter. As compared with the first instar, the first three abdominal segments are not so distinctly larger than the rest, the constrictions between the segments are less deep, and the rudimentary prolegs of the third abdominal segment are less apparent, while those on the fourth have become functional. Body tubercles nearly circular, slightly elevated, and same color as surrounding tissue; setæ fine, long, and pale.

Third instar.—Length 8 to 11 millimeters, head width 0.635 to 0.753 millimeter. Abdomen tapering slightly to caudal extremity, with constrictions between segments moderately deep. Prolegs on fourth, fifth, and last abdominal segments functional. At the second molt the vestigial prolegs on the third abdominal segment entirely disappear. Body chitinizations more elevated than in previous instar, otherwise the same. Setæ for the most part long and black. Body shiny yellowish-green, dorsal vessel darker green, accentuated by a faintly whitish-mottled border, a narrow mottled whitish stripe on a line just outside the posterior dorsal chitinizations, and another through the spiracles. These white stripes are not found on all larvæ in this instar, as individuals vary in this respect.

Fourth instar.—Length 11 to 19 millimeters, head width 0.886 to 1.166 millimeters. Body tapering gradually from sixth to caudal segments, moderately constricted between segments. Body shiny yellowish-green, with dark green middorsal line bordered on each side by a mottled whitish line, the narrow subdorsal stripe along the outside margin of posterior dorsal chitinizations more distinct than in preceding instar, and the lateral stripe on a line with spiracles wider, and more distinct than the others. Spiracles appearing as small white dots, those on prothorax larger and showing a fine dark edge.

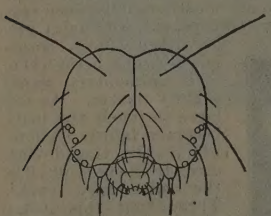

FIG. 6.—Dorsal view of head of larva of green clover worm

Fifth instar.—Length 16 to 23 millimeters, head width 1.306 to 1.586 millimeters. Body widest along first three abdominal segments, tapering slightly toward each extremity. Constrictions between segments less pronounced than in previous instars, and the three pairs of longitudinal white stripes more distinct, though varying with individuals, head and body otherwise the same. Setæ for the most part moderately long and dark. Spiracles small, oval, white, with dark edges.

Sixth instar.—Length 18 to 31 millimeters, head width 1.866 to 2.052 millimeters. Body with first four abdominal segments nearly uniform in width, thence tapering gradually toward each extremity. Constrictions between segments slight. Prolegs functional on fourth, fifth, sixth, and last abdominal segments, pedal hooks 17 to 24. Head (fig. 6) subspherical, flattened, oblique, with emargination at vertex moderately deep; pale yellowish-green, tips of mandibles dark, ocelli black, labrum and outer edge of mandibles distinctly whitish; face sparsely setose with a conspicuously long seta near middle of each side of epicranium. Mandible (fig. 7) short and stout, with three distal teeth and one broad cutting projection on inside. Cervical shield with convexity caudad, bearing four long, dark setæ inclined cephalad along cephalic margin and four smaller ones along caudal margin (fig. 8, TI, 1a, 1b, 2a, 2b). Prothoracic spiracle near caudal margin of segment, oval, white, with dark edge,

FIG. 7.—Mandible of larva of green clover worm

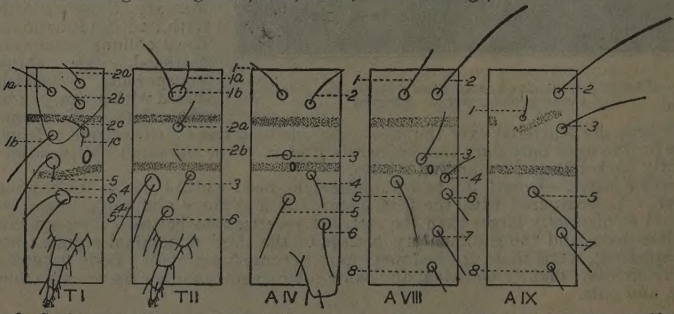

FIG. 8.—Setal maps of first and second thoracic and fourth, eighth, and ninth abdominal segments of larva of green clover worm: TI, Prothorax; TII, mesothorax; AIV, fourth abdominal segment; AVIII, eighth abdominal segment; AIX, ninth abdominal segment

Three oval, slightly elevated bisetose chitinizations are grouped around it, one dorsad, one cephalad, and one ventro-cephalad, all concolorous with surrounding tissue except at immediate bases of setæ (fig. 8, TI). Mesothorax and metathorax with one pair of bisetose chitinizations on dorsum, and on latus three unisetose and one bisetose chitinizations (fig. 8, TII), and one fine pale seta (2b) half way between setæ 2a and 3. On each of the first six abdominal segments there are six pairs of unisetose chitinizations, two on dorsum, bearing setæ 1 and 2, and four on latus, bearing setæ 3, 4, 5, and 6 (fig. 8, AIV); the three lateral chitinizations, bearing setæ 3, 4, and 5, form points of a triangle with the cephalic side longest and on a line with the spiracles, chitinization bearing seta 6 close to venter. Eighth abdominal segment (fig. 8, VIII) with setæ 1 and 2 nearly in alignment with each other, two setæ (4 and 6) caudoventrad of spiracle, seta 5 more dorsad than on the other segments, and setæ 7 and 8 on ventrum; ninth abdominal segment (fig. 8, AIX) with setæ 1, 2, and 3 forming nearly an equilateral triangle, setæ 4 and 6 missing, and setæ 7 and 8 nearly as on the eighth abdominal segment; all chitinizations nearly circular, slightly elevated, and of the same color as the surrounding tissue except for dark areas surrounding the immediate bases of the setæ. Setæ moderately long and dark. Abdominal spiracles oval, white, with dark rims. Body with a distinct white lateral stripe through spiracles, a narrow whitish subdorsal stripe along outer edge of posterior dorsal chitinizations, less distinct than in preceding instar, and the dorsal vessel dark green with paler green tissue on either side.

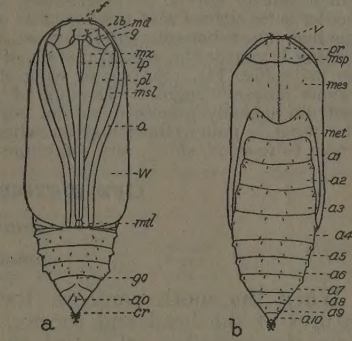

FIG. 9.—Pupa of the green clover worm: *a*, Ventral view; *b*, dorsal view. *a*, Antenna; a^1 to a^{10}, abdominal segments of pupa; *ao*, anal opening; *cr*, cremaster; *f*, front; *g*, gena; *go*, genital opening; *lb*, labrum; *lp*, labial palpi; *md*, mandible; *mes*, mesothorax; *met*, metathorax; *msl*, mesothoracic leg; *msp*, mesothoracic spiracle; *mtl*, metathoracic leg; *mx*, maxilla; *pl*, prothoracic leg; *pr*, prothorax; *v*, vertex; *w*, mesothoracic wing

PREPUPAL STAGE

The body is considerably shorter than that of the full-grown larva, and in natural position remains slightly curved. It is robust with greatest width near middle, but tapers rather sharply toward caudal extremity; the head and prothorax are nearly the same width; the mesothorax is wider and the longest

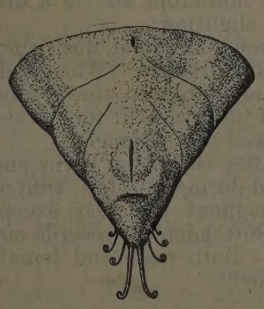

FIG. 10.—Caudal end of female pupa of the green clover worm. Enlarged

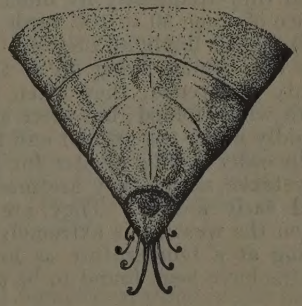

FIG. 11.—Caudal end of male pupa of the green clover worm. Enlarged

segment in the body. General color pale green with a dark green middorsal stripe, and a similar though slightly broader lateral stripe running on a line just dorsad of spiracles. Longitudinal white markings entirely lacking; ocelli no longer black but concolorous with face; spiracles transversely oval, white in color, edged with brown. Pedal extremities retracted, leaving skin loose. As pupation approaches, the body becomes sufficiently contracted to leave the skin around the caudal extremity wrinkled.

THE PUPA (FIG. 9)

Length of female 11 to 13 millimeters, average 12.17 millimeters; male 12 to 15 millimeters, average 13.71 millimeters. Width about 4.5 millimeters. Body subcylindrical, with abdomen acute. Two pairs of minute setæ on front and other minute setæ sparsely distributed over rest of body. Cremaster with two stout spines bluntly curved at extremities, and on each side near their bases three smaller setæ curved and thickened at extremities. The spiracles are transverse openings on tubercular prominences. In the female (fig. 10) the genital opening is nearer the caudal margin of the seventh abdominal segment than in the male (fig. 11). Surface of wing sheaths and prothoracic and mesothoracic regions coarsely rugose. Dorsum of abdominal segments coarsely punctate, ventrum sparsely punctate; caudal border of each abdominal segment smooth. The pupa is pale yellowish-green when first formed but soon turns chestnut-brown to fuscous, shiny, and sometimes almost black before emergence occurs.

LIFE HISTORY AND HABITS

ADULT STAGE

EMERGENCE

When the moth emerges, the pupal skin is broken along the sutures of the head and thorax. One moth, after detaching itself from the case, was observed to crawl rapidly away, coming to a standstill with head upward on the stem of an alfalfa plant on which it was allowed to crawl. Its wings, which were at first short, attained full growth in the course of eight minutes.

HABITS IN THE FIELD

During the day the moths stay in hiding on the under side of leaves or grass blades, sometimes in tree tops, and frequently under the eaves and on the walls of barns and houses, where their dark color enables them to escape notice. At dusk they become active and in warm weather may be observed in the fields feeding on the nectar of the blossoms of their host plants and flitting from plant to plant. Their flight is zigzag and undulating, and on alighting they quickly dart to the under side of the leaf or other object. If pursued they frequently fly much higher than housetops and to a distance of some 50 to 100 yards away before alighting.

In broad daylight they are not easily aroused; but at dusk they are very timid, flying up at the slightest disturbance. When suddenly frightened, they often feign death and drop to the ground with wings folded; but after an interval, if undisturbed, they crawl rapidly along the ground and fly up when well out of danger.

In order to find shelter for hibernation they collect on barns and haystacks, where they are most often found during late fall, winter, and early spring. They are active throughout the year, except when the weather is extremely cold, and Chittenden (*2*) records one flying at a temperature as low as 51° F. Both male and female moths have been found to be attracted by lights.

OVIPOSITION

When ovipositing the moth partially raises her body and, while slightly retracting and extending her ovipositor, curves the end of her abdomen downward, its tip almost touching the surface on which she rests. After several minutes in this attitude, a single egg is quickly deposited. She then moves on to another resting place,

and in this manner locates the eggs, one at a time, on the foliage of the food plant. In alfalfa and clover fields the writer has found the eggs nearly always on the under side of the foliage to the number usually of one, and never more than four on a leaflet.

In order that data might be procured as to the number of eggs the female of this species usually lays in the course of her life, individuals were captured in the field and confined for the most part in vials provided with fresh leaves of food plants and bits of moist blotting paper. Table 1 shows egg records of 24 of these moths. The maximum number of eggs laid by a single female was 670. Moths captured by the writer late in the fall refused to oviposit.

TABLE 1.—*Data on oviposition and longevity of moths of the green clover worm captured in the field, 1916*

No.	Date of capture	Date first egg was laid	Date last egg was laid	Length of oviposition period	Number of eggs laid	Date of death	Length of life in captivity
				Days			*Days*
1	Mar. 25	Mar. 26	Apr. 4	9	175	Apr. 5	11
2	30	Apr. 1		12	270	13	14
3	30	1	3	2	60	4	5
4	Apr. 3	4	9	5	216	10	7
5	3	4	10	6	125	11	8
6	3	5	10	5	98	10	7
7	3	5	12	7	198	15	12
8	3	4	8	4	155	10	7
9	7	13	21	8	266	23	16
10	7	8	18	10	120	23	16
11	12	15	16	1	114	16	4
12	12	15	16	1	135	17	5
13	12	13	22	9	227	23	11
14	18	19	21	2	107	22	4
15	July 25	July 25–26	July 26	1	121	July 27	2
16	25	25–26	27	1	212	29	4
17	25	25–26	31	5	300	Aug. 1	7
18	25	25–26	28	2	153	July 28	3
19	25	25–26	27	1	224	28	3
20	25	25–26	Aug. 1	6	137	Aug. 1	7
21	25	25–26	4	9	670	6	12
22	25	26–27	3	7	193	6	12
23	25	25–26	3	8	345	6	12
24	25	25–26	July 26	1	208	29	4

The oviposition period may last 11 days or more, and during the spring and summer months extends throughout most of the life of the adult.

It was observed that moths kept in captivity would seldom deposit large batches of eggs on consecutive days, but would rest from egg laying for a day or two after such exertions. One female oviposited on consecutive days, as follows: 168, 8, 159, 83, 0, 0, 161, 0, 60, 31; another: 119, 40, 59, 0, 0, 11, 0, 110, 6. The greatest number of eggs laid during any one period of 24 hours was 208.

LONGEVITY OF ADULT

Table 1 shows the length of life of 24 females captured in the field during the spring and summer months. It will be observed that the longest time any individual lived was 16 days. As a check on this record, which includes only moths captured in the field, a few records were obtained from adults reared in confinement. Table 2 shows the results obtained. The average length of life in this experiment came

to 7 days. During the winter the life of the moth is greatly extended, because of hibernation.

TABLE 2.—*Longevity of moths of the green clover worm reared in confinement*

No.	Sex	Date of emergence	Date of death	Length of life
				Days
1	Female	Oct. 14	Oct. 22	8
2	Male	18	25	7
3	Female	16	25	9
4	Female	28	Nov. 2	5
Extremes				5 and 9
Average				7.25

EGG STAGE

Table 3 shows the length of the period of incubation of eggs laid by moths in captivity. During the summer and early fall months eggs hatched in from 2 to 5 days, but during cool weather in the spring the incubation period was lengthened to as many as 14 days.

TABLE 3.—*Length of incubation period of eggs of the green clover worm*

Egg lot No.[1]	Laid—	Hatched—	Incubation	Egg lot No.	Laid—	Hatched—	Incubation
	1916	1916	*Days*		1916	1916	*Days*
1	Mar. 26	Apr. 2	7	19	Apr. 20	May 1	11
2	27	4	8	20	22	1	9
3	28	4	7				
4	30	13	14	Spring average			9.45
5	Apr. 1	13	12				
6	2	14	12	1	July 26	July 31	5
7	3	14	11	2	27	Aug. 1	5
8	4	15	11	3	28	1	4
9	5	15	10	4	Aug. 1	3	2
10	6	18	12	5	11	15	4
11	8	14	6	6	25	29	4
12	9	17	8				
13	13	22	9		1915	1915	
14	14	22	8	7	Sept. 8	Sept. 12	4
15	15	23	8	8	10	13	3
16	16	24	8				
17	17	26	9	Summer and early fall average			3.88
18	18	27	9				

[1] Each lot contained from 15 to 1,104 eggs.

LARVAL STAGE

GENERAL HABITS

In hatching, the larva eats a ragged hole at one side of the apex of the egg just large enough to permit exit. It then works its way slowly out and at once searches for food. During the first three instars the larva, when feeding on alfalfa, skeletonizes the leaf, leaving the upper epidermis intact; but beginning with the fourth instar it eats entirely through, avoiding only the larger veins. On large-leaved plants, such as soybean, the larvæ are usually found stretched out on the under side of a leaflet; but on plants with smaller foliage they commonly feed extended along the stem, and in these positions their color blends

with the foliage and renders detection difficult. The injury resulting from the work of this caterpillar is of a scattered character, giving the field a ragged appearance. Figure 12 shows a soybean leaf eaten in a characteristic manner. This distribution of injury may partly be accounted for by the readiness with which the larvæ leap off a plant even when slightly disturbed. The larvæ, most noticeably the young ones, have the habit when molested of sharply bending their bodies somewhat like a jackknife instead of coiling them.

FIG. 12.—Soybean leaf eaten in characteristic manner by the green clover worm

QUANTITIES OF FOOD EATEN

In order to ascertain the quantity of foliage eaten by a single caterpillar in the course of its life, a series of larvæ were supplied with measured quantities of cowpea and alfalfa leaf, and it was found that the average larva consumed foliage equivalent to about 19 average-sized leaflets of alfalfa. Table 4 shows the average quantity eaten by each of five larvæ during the first five instars, and by each of four during the sixth.

TABLE 4.—*Quantity of foliage eaten by larvæ of the green clover worm*

Instar	Square millimeters
First	3. 9
Second	34
Third	84
Fourth	117
Fifth	624
Sixth	1, 660
Total	2, 522. 9

LARVAL DEVELOPMENT

The larva molts five times in the course of its development, although in exceptional instances individuals have been observed to undergo six molts. Table 5 shows the length of the instars from records of 33 larvæ reared during summer and fall seasons in Tennessee. The rearings were conducted in an outdoor insectary under conditions and temperatures approximating the natural environment. The average length of the larval period came to 22.84 days.

TABLE 5.—*Lengths of larval instars of the green clover worm*

Instar	Number reared	Instar lengths		
		Maximum	Minimum	Average
		Days	*Days*	*Days*
First	33	4	2	3.09
Second	33	4	2	2.21
Third	33	3	2	2.36
Fourth	33	5	2	3.27
Fifth	33	6	2	3.64
Sixth	33	14	5	8.27
Total				22.84

In the course of the larva's growth the size of its head increased with each molt but remained constant throughout each instar, thus forming a reasonably safe guide for determining the instar. Table 6 gives the head widths by instars from numerous measurements.

TABLE 6.—*Head widths of green clover worm larvæ at different stages of growth*

Instar	Number measured	Width		
		Maximum	Minimum	Average
		Millimeters	*Millimeters*	*Millimeters*
First	6	0.285	0.265	0.268
Second	6	.459	.353	.403
Third	10	.753	.635	.713
Fourth	11	1.166	.886	.996
Fifth	11	1.586	1.306	1.454
Sixth	5	2.052	1.866	1.940

The measurement of the length of the caterpillar can also be used to some extent to indicate the instar, although the degree of individual variation in length is much greater than for the head width. Table 7 may be used as a guide in this respect.

TABLE 7.—*Larval lengths of the green clover worm at different stages of growth*

Instar	Maximum	Minimum	Length of larva	
			Average at end of instar	Average at beginning of instar
	Millimeters	*Millimeters*	*Millimeters*	*Millimeters*
First	4.0	1.5	3.58	1.50
Second	7.5	3.5	6.55	3.58
Third	11.0	8.0	10.17	6.55
Fourth	19.0	11.0	15.59	10.17
Fifth	23.0	16.0	20.68	15.59
Sixth	31.0	18.0	28.60	20.68

RESISTANCE TO FROST

The larvæ of *Plathypena scabra* are known to survive ordinary frosts, but eventually succumb to continued cold weather. None have been found alive in the field in the vicinity of Nashville, Tenn., later than October 18. W. R. McConnell reported finding numerous live larvæ in a plot of soybeans at Greenwood, Miss., as late as

October 29. On November 14, however, many of them were observed to be dead on the outer leaves, having been killed by heavy frosts that occurred during the preceding three nights, although a few larvæ were still alive in protected places. Subsequently no living larvæ were to be found, and their disappearance was attributed to the cold weather. At Nashville, Tenn., eight healthy larvæ were placed in the field on an alfalfa plant, under a wire cage, and a thermograph was installed near by. A minimum temperature of 34° F. killed three of these larvæ the first night. The next night two more succumbed to a temperature of 31° F., but the remaining three survived a temperature of 26° F. and two of them eventually pupated, one later emerging as a moth.

PREPUPAL STAGE

When mature, the larva stops feeding, descends to the earth, and on or partly beneath the surface thereof constructs an oval cocoon (fig. 13) of earthen particles or bits of rubbish and leaves loosely webbed together. If no débris be present, plain silken cases are spun, protected on one side by some object. Within the cocoon the larva lies at first in a curved position, which gradually becomes less pronounced as the body contracts. This period lasts from one to six days, with an average of about two days in warm weather.

PUPAL STAGE

The pupal stage ordinarily covers a period of from 7 to 24 days, as shown in Table 8, data for which were obtained from 20 pupæ reared from May 20 to November 3. There is evidence, however, that this species sometimes hibernates as a pupa. From a number of pupæ formed between October 8 and 19 and exposed to outdoor conditions, the moths failed to emerge at the usual time; but when these were brought indoors late in November one adult emerged, having passed a pupal period of 42 days, and another came out December 2 after a pupal period of 44 days.

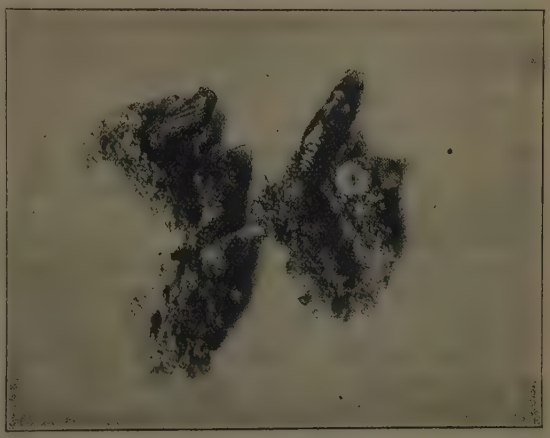

FIG. 13.—Cocoons with pupæ of the green clover worm partly out of them

TABLE 8.—*Length of pupal stage of the green clover worm*[1]

No.	Date of pupation	Date of emergence	Number of days	No.	Date of pupation	Date of emergence	Number of days
1	May 20	May 30	10	13	Aug. 12	Aug. 24	12
2	...do...	May 31	11	14	Aug. 14	Aug. 23	9
3	June 19	June 27	8	15	Aug. 25	Sept. 8	14
4	...do...	June 28	9	16	Sept. 1	Sept. 15	14
5	June 22	June 29	7	17	...do...	Sept. 21	20
6	...do...	June 30	8	18	Oct. 4	Oct. 28	24
7	June 23	July 1	8	19	Oct. 6	Oct. 29	23
8	July 1	July 10	9	20	Oct. 14	Nov. 3	20
9	...do...	July 12	11				
10	July 2	...do...	10	Average			12.1
11	July 5	...do...	7	Maximum			24
12	...do...	July 13	8	Minimum			7

[1] The data for the months of June and July were obtained by F. M. Moody.

SUMMARY OF LIFE CYCLE

The egg-laying period of the moth may last for a period of 11 days or more, the egg hatching during the summer and early fall in about 4 days. The larval period lasts about 23 days, in the course of which the caterpillar molts five times and spends approximately two days as a prepupa inside the cocoon. The pupal period lasts from 7 to 24 days, except when lengthened by hibernation. Table 9 gives the average lengths of the different stages.

TABLE 9.—*Summary of duration of stages of development of the green clover worm*

Stage	Average period
	Days
Egg	3.88
Larva	22.84
Pupa	12.10
Total	38.81

SEASONAL HISTORY

NUMBER OF GENERATIONS A YEAR

During the season of 1916 at Knoxville, Tenn., four distinct generations were found to occur. Certain heavily infested alfalfa fields on the farm of the State Agricultral Experiment Station were visited every few days, and records were kept of the varying abundance of the different stages of this species. Parts of these fields were standing throughout the season, which eliminated the interference of cutting with the development of the generations. Figure 14

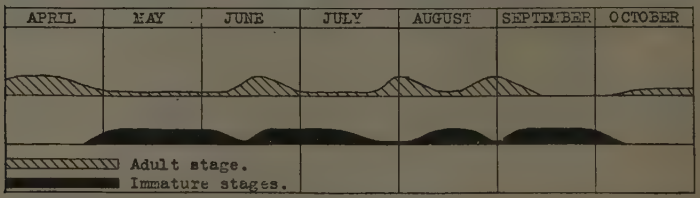

FIG. 14.—Diagram showing the number of generations of the green clover worm during the year 1916 at Knoxville, Tenn.

shows the periods of occurrence of the adult and immature stages, as found from April to October, inclusive. Adults in abundance were noted about the first of April and remained fairly numerous until the middle of that month. By April 27 young larvæ of the first generation appeared, and larvæ were found abundantly distributed over the fields throughout the month of May. In the interval the moths nearly disappeared, and only a few battered individuals could be found until about the middle of June, when freshly emerged moths began to appear in great numbers. During the middle and last of June young larvæ of the second generation became plentiful in the field and remained very numerous until the second week in July, by which time they had reached full growth and were pupating. By July 18 newly emerged moths from this second generation began to appear, and by July 24 they were found in great numbers in the field. The third generation of larvæ, resulting from eggs laid by these moths, were present in the field in abundance by the second week in August, and adults, although present in the field, were greatly diminished in numbers. During this time the weather was warm and the caterpillars were maturing rapidly. By August 22 practically all of these had pupated and newly emerged moths were becoming numerous. Young larvæ of the fourth generaton were found about the 1st of September, but by the 12th only a few battered moths were present. Larvæ continued abundant throughout the remainder of the month. In October a few freshly emerged adults were collected.

According to certain authors (*4*, *10*), the number of generations is fewer farther north, decreasing to three and even two per annum.

HIBERNATION

Observations indicate that hibernation takes place in both the pupa and adult stages. Although repeated attempts to carry the moths through the winter in cages failed, yet in the field at Nashville, Tenn., they were found numerous during October and part of November, and again during the first warm days of February. Philip Luginbill observed five moths flying in a woodshed at Columbia, S. C., on January 5. Chittenden (*2*) observed that "About the city of Washington this moth is one of our latest as well as earliest species, individuals occurring commonly in the writer's experience about the Department of Agriculture buildings throughout November, as late as the first week in December, and as early as March 10." Riley (*9*) reported a large number of these moths transmitted to Washington during the winter by correspondents who confused it with moths of the cotton leafworm (*Aletia*) *Alabama argillacea* Hbn.

As stated in the discussion of the pupal stage, pupæ formed late in the fall at Knoxville, Tenn., failed to produce adults until brought into the heated laboratory. If left in the field, they might have passed the winter in this stage. One pupa in an outdoor cage remained alive as late as December 22. In this connection it might be mentioned that Riley (*9*) stated that pupæ were found in Missouri throughout the winter.

NATURAL ENEMIES

Ten species of parasites were reared from *Plathypena scabra* collected in Tennessee, and 18 more have been reported from other localities. Fourteen of these are Hymenoptera and 14 Diptera. Predators and fungi were also found to attack this insect extensively.

HYMENOPTERA.

Apanteles harnedi Vier.[3] was reared by the writer from larvæ collected at Nashville and Knoxville, Tenn., in the years 1914, 1915, and 1916, and by C. L. Scott at Brownsville, Tex., March 30, 1913.

A campoplegine, probably a new species and new genus, was recorded by Sherman (*10*) as reared in North Carolina.

Euplectrus comstockii How. was reported by C. N. Ainslie as very commonly parasitizing *Plathypena scabra* in the vicinty of Elk Point, S. Dak.

Euplectrus platyhypenae How. was reared from this host at Washington, D. C., on July 11, 1882, from material collected in that vicinity, and was described by Howard (*6*) who named it after the genus Plathypena.

Hemiteles sp.[4] was reared by P. Luginhill at LaFayette, Ind., April 2, 1912.

Meteorus sp.; one specimen [5] was reared by the writer at Nashville, Tenn., in 1915.

Mesochorus sp.; a single specimen [5] was reared by the writer at Nashville, Tenn., in 1915.

Microgaster facetosa Weed [6] was reared from this host at Knoxville and Nashville, Tenn., by the writer, and at Hagerstown, Md., by H. L. Parker (*8*).

Microplitis varicolor Vier. was reared from this host at Columbia, S. C., by R. J. Kewley, and by the writer at Nashville, Tenn. (*8*).

Rhogas canadensis Cress.; a single specimen [7] was reared from *Plathypena scabra* by Philip Luginbill at LaFayette, Ind., in 1911.

(*Rhogas*) *Aleiodes intermedius* Cress. was reported by Hawley (*4*) as reared from a *P. scabra* larva collected in New York.

Rhogas nolophanae Ashm.[8] was the most common parasite at Nashville, Tenn., in 1914. It was reared from larvæ collected in the spring, the adults first appearing about the 20th of May. The cocoon is yellowish-brown, slender, from 8 to 10 millimeters long by 1.75 millimeters wide, and formed from the shrunken and stiffened skin of the caterpillar. Not more than one individual was reared from a single host. Six specimens each passed eight days in the cocoon. The exit hole is made on the dorsum in the vicinity of the sixth and seventh abdominal segments.

Rhyssalus loxoteniae Ashm. was reported by Hawley (*4*) as reared from a larva of this insect collected in New York.

Trichogramma pretiosa Riley was recorded by Sherman (*10*) as being a very common parasite of the egg in North Carolina.

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[3] Four specimens reared in Tennessee determined by A. B. Gahan.
[4] One specimen determined by H. L. Viereck.
[5] Determined by A. B. Gahan.
[6] Eleven specimens from Knoxville, Tenn., determined by A. B. Gahan.
[7] Determined by H. L. Viereck.
[8] Nine specimens determined by A. B. Gahan.

DIPTERA

One male of *Compsilura concinnata* Meig. was reared from a *Plathypena scabra* pupa, the larva of which was collected at Indian Orchard, Mass., by D. A. Ricker. This tachinid was imported from Europe to aid in controlling the gipsy and brown-tail moths in New England and has proved a very effective enemy against them. It was first introduced in 1906, but the most satisfactory colonies were planted in 1909. It is known to parasitize a large number of hosts in Europe and has already been reared from a number of native hosts.

Exorista blanda O. S. is recorded by Chittenden (*2*) as having been reared from the pupa of *Plathypena scabra* September 7, 1899.

Exorista amplexa Coq.[9] was reared from this host at Hagerstown, Md., by C. M. Packard in 1914.

Hypochaeta eudryae Smith [10] was reared by the writer at Knoxville, Tenn., in 1916. Those observed emerged from the larva stage of the host and formed puparia about 5 millimeters long.

Hypochaeta longicornis Schiner [11] was reared by W. R. McConnell at Greenwood, Miss., September 9, 1913.

Phorocera flavicauda V. d. W.[12] was reared by E. H. Gibson at Greenwood, Miss., in 1913 and by the writer at Knoxville, Tenn., in 1916.

Phorocera claripennis Macq.[11] was reared by W. E. Pennington from a larva collected at Hagerstown, Md. The host larva was collected June 21, 1915; the dipterous puparium was formed July 6; the dipteron adult emerged July 15.

Trichophora ruficauda V. d. W.[13] was more abundant at Knoxville, Tenn., in 1916 than any other parasite reared from *Plathypena scabra*. Specimens of this tachinid were also reared by the writer at Nashville, Tenn., in 1915; and by E. H. Gibson at Greenwood, Miss., in 1913, F. M. Moody at Charleston, Mo., and R. W. Leiby at Terra Ceia, N. C. (*10*). The host caterpillars of specimens reared at Knoxville each showed a dark spot bearing a small round pore opening through the skin and through which in some cases the movements of the parasitic larva could be seen. On the pupation of the host this pore was retained and enlarged, and usually occurred between the second and fifth abdominal segments. The puparium as a rule was left inside the pupal skin, filling all but the tip of the abdomen. One which was protruding from the host when the latter was in the prepupal stage is shown in Figure 15.

FIG. 15.—Photograph showing a puparium of *Trichophora ruficauda* partially protruding from its host, a larva of the green clover worm

[9] Determined by W. R. Walton.
[10] Seven specimens determined by W. R. Walton.
[11] One specimen determined by W. R. Walton.
[12] Four specimens from Tennessee determined by W. R. Walton.
[13] Sixteen specimens reared in Tennessee determined by W. R. Walton.

Winthemia quadripustulata Fab.[14] was reared by F. M. Moody at Charleston, Mo., and by the writer at Knoxville, Tenn., in 1916. The caterpillars from which the latter were reared each bore two small, oval white eggs on its thorax; and, when swept from the field, one was a prepupa, while the other was still feeding. The former pupated a few days after capture, and when examined three days later a large puparium was found filling over two-thirds of its interior, leaving only the end of the abdomen empty. The other caterpillar also pupated; but in this case the parasite larva, a yellowish-white maggot 8 millimeters long, emerged from the pupa and formed its puparium outside.

In addition to the foregoing Diptera, Sherman (*10*) listed as reared in North Carolina the following five species:

Bombyliidae: *Anthrax lateralis* Say.

Tachinidae: *Euphorocera floridensis* Tns., *Exorista boarmiae* Coq., *Frontina aletiae* Riley.

Sarcophagidae: *Sarcophaga cimbicis* Tns.

HEMIPTERA

NABIDAE

Nabis ferus L.[15]—This slender gray bug has been found in the field at different times feeding on the young *Plathypena scabra*. As it has usually been found exceedingly abundant in infested fields in Tennessee examined by the writer, it undoubtedly aids considerably in the destruction of the caterpillars. The nymphs as early as the first and second instars have been observed to attack and kill the young arvæ. Bugs kept in captivity deposited eggs in rows along the stems of the alfalfa plants, each egg inserted deeply, with only one end showing on the surface as a tiny white spot.

PENTATOMIDAE

Podisus maculiventris Say, the spined soldier-bug, has been found numerous in infested fields and undoubtedly kills many of the caterpillars. One bug was found in the field with a *Plathypena scabra* larva pierced by its beak. This specimen was determined as *Podisus maculiventris* Say by O. Heidemann. Individuals kept in captivity fed readily on the caterpillars, one destroying five in the course of five days' captivity. It pierced the larva with its beak and sucked its contents, leaving only a shrunken remnant of skin and solid parts.

FUNGOUS DISEASE

In the fall of the year great numbers of larvæ are killed off by the fungus *Botrytis rileyi* Farl.[16] Both at Knoxville and Nashville, Tenn., they have been severely attacked by this disease, and similar reports have come from Hagerstown, Md.

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[14] Three specimens from Tennessee determined by W. R. Walton.

[15] An individual found by the writer feeding on a *Plathypena scabra* larva was identified by Herbert Osborn as *Nabis ferus* L.

[16] Infestation on *Plathypena scabra* larvæ collected by the writer at Knoxville, Tenn., was determined as this fungus by Alden T. Speare.

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